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Application No.	Country of Origin	Filed
02254786.3	Europe	July 9, 2002

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Attestation

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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

02254786.3

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Lithographic apparatus and device manufacturing method

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Lithographic Apparatus and Device Manufacturing Method

The present invention relates to a lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- a support structure for supporting programmable patterning means, the programmable patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate; and
- a projection system for projecting the patterned beam onto a target portion of the substrate.

The term "programmable patterning means" as here employed should be broadly interpreted as referring to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate; the terms "light valve" and "spatial light modulator" can also be used in this context. Generally, the said pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device (see below). Examples of presently used programmable patterning means include:

- A programmable mirror array. One example of such a device is a matrix-addressable surface having a viscoelastic control layer and a reflective surface. The basic principle behind such an apparatus is that (for example) addressed areas of the reflective surface reflect incident light as diffracted light, whereas unaddressed areas reflect incident light as undiffracted light. Using an appropriate filter, the said undiffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind; in this manner, the beam becomes patterned according to the addressing pattern of the matrix-addressable surface. An alternative embodiment of a programmable mirror array employs a matrix arrangement of tiny mirrors, each of which can be individually tilted about an axis by applying a

suitable localized electric field, or by employing piezoelectric actuation means. Once again, the mirrors are matrix-addressable, such that addressed mirrors will reflect an incoming radiation beam in a different direction to unaddressed mirrors; in this manner, the reflected beam is patterned according to the addressing pattern of the matrix-addressable mirrors. The required matrix addressing can be performed using suitable electronic means. In both of the situations described hereabove, the patterning means can comprise one or more programmable mirror arrays. More information on mirror arrays as here referred to can be gleaned, for example, from United States Patents US 5,296,891 and US 5,523,193, and PCT patent applications WO 98/38597 and WO 98/33096, which are incorporated herein by reference. In the case of a programmable mirror array, the said support structure may be embodied as a frame or table, for example, which may be fixed or movable as required.

- A programmable LCD array. An example of such a construction is given in United States Patent US 5,229,872, which is incorporated herein by reference. As above, the support structure in this case may be embodied as a frame or table, for example, which may be fixed or movable as required.

For purposes of simplicity, the rest of this text may, at certain locations, specifically direct itself to examples involving a mask and mask table; however, the general principles discussed in such instances should be seen in the broader context of the patterning means as hereabove set forth.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the patterning means may generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (*e.g.* comprising one or more dies) on a substrate (silicon wafer) that has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions that are successively irradiated via the projection system, one at a time. In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus —

commonly referred to as a step-and-scan apparatus — each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned, for example, from US 6,046,792, incorporated herein by reference.

In a manufacturing process using a lithographic projection apparatus, a pattern (e.g. in a mask) is imaged onto a substrate that is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4, incorporated herein by reference.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a “lens”. Further, the lithographic apparatus may be of a type having two or

more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in US 5,969,441 and WO 98/40791, incorporated herein by reference.

In order to meet the demand for forming ever-smaller components on the devices produced with lithographic projection apparatus, shorter wavelength radiation, such as EUV radiation, must be used. However, conventional programmable patterning means are not suitable for use with EUV radiation. For example, the surface tension in the multilayer stacks used to reflect EUV light is very high and would bend the elements in a conventional spatial light modulator.

It is an object of the present invention to provide a lithographic projection apparatus with a programmable patterning means that is suitable for use with EUV radiation.

This and other objects are achieved according to the invention in a lithographic apparatus as specified in the opening paragraph, characterized in that the programmable patterning means comprises a plurality of reflective elements, each comprising first and second distributed Bragg reflectors and a means for adjusting their separation; wherein, in a first position, the separation of the first and second distributed Bragg reflectors produces destructive interference between the reflections from the first and second distributed Bragg reflectors and the reflectivity of the reflective element is relatively low; and, in a second position, the separation of the first and second distributed Bragg reflectors produces constructive interference between the reflections from the first and second distributed Bragg reflectors and the reflectivity of the reflective element is relatively high.

This arrangement provides a programmable patterning means in which each reflective element may be controlled to switch between relatively high and relatively low reflections at a particular wavelength of radiation. Therefore by setting different reflective elements to different states, the programmable patterning means may impart the desired pattern to the beam.

The actuator used for adjusting the separation of the first and second distributed Bragg reflectors in each reflective element may also set the separation to be one of a plurality of positions, setting the reflectivity of the reflective element to be at a plurality of levels between the first position, in which the reflective is substantially zero, and the second position, in which the reflectivity is a maximum. This facilitates better control of the pattern imparted to the projection beam.

For ease of manufacturing the programmable patterning means, two or more of the reflective elements may have a common first distributed Bragg reflector. The reflectivity of each of the reflective elements is then be set by moving the second distributed Bragg reflectors relative to the common first distributed Bragg reflector.

Preferably, the projection beam of radiation is EUV radiation, the distributed Bragg reflectors are designed to be individually reflective of EUV radiation at the wavelength used and the difference in the separation of the first and second distributed Bragg reflectors between the first and second positions is approximately one quarter of the wavelength of the EUV radiation used. This arrangement provides the greatest contrast between the reflective elements' maximum and minimum reflectivity.

The means of adjusting the separation of the first and second distributed Bragg reflectors may be a piezoelectric-actuator. The performance of such actuators is well understood and it is possible to control the movement of such piezoelectric-actuators to a very high level of accuracy. This is required since the range of movement of the piezoelectric-actuator will be of the order of a few nanometers and the required accuracy will be in the sub-nanometer range. For example, to provide 10 grey levels between the first and second positions, the difference between the separation at adjacent positions will be approximately 0.2 to 0.5 nm.

Each reflective element may have an individual piezoelectric element for moving one of its distributed Bragg reflectors. Alternatively, two or more of the reflective elements may have a common piezoelectric element. This is possible because the piezoelectric effect is local to the electrode at which the voltage is supplied to the piezoelectric element. The local effect may be use to separately adjust the position of the distributed Bragg reflectors in each reflective element. Using a common piezoelectric element may significantly simplify the production of the programmable patterning means.

As a further alternative, the means for adjusting the separation of the first

and second distributed Bragg reflectors may be by means of an electrostatic actuator. This may reduce the complexity of the programmable patterning means and facilitate its manufacture since it does not require the provision of piezoelectric elements.

According to a further embodiment of the present invention, there is provided a lithographic projection apparatus comprising:

- a radiation system for providing a projection beam of radiation;
- a support structure for supporting programmable patterning means, the programmable patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate;
- a projection system for projecting the patterned beam onto a target portion of the substrate,

characterized in that the programmable patterning means comprises a plurality of reflective elements, each comprising a distributed Bragg reflector and a means for adjusting the position of each distributed Bragg reflector relative to the programmable patterning means such that a phase difference can be created between the reflection from a first reflective element and the reflection from a second reflective element.

According to a further aspect of the invention there is provided a device manufacturing method comprising the steps of:

- providing a substrate that is at least partially covered by a layer of radiation-sensitive material;
- providing a projection beam of radiation using a radiation system;
- using programmable patterning means to endow the projection beam with a desired pattern in its cross-section;
- projecting the patterned beam of radiation onto a target portion of the layer of radiation-sensitive material,

characterized by said programmable patterning means comprising a plurality of reflective elements, the reflectivity of each of which being determined by the distance between a pair of distributed Bragg reflectors that comprise each reflective element; and by the method further comprising the step of setting the distance between each said pair of distributed Bragg reflectors to provide the desired reflectivity of each reflective element in accordance with said desired pattern.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

In the present document, the terms “radiation” and “beam” are used to encompass all types of electromagnetic radiation, including ultraviolet radiation (*e.g.* with a wavelength of 365, 248, 193, 157 or 126 nm) and EUV (extreme ultra-violet radiation, *e.g.* having a wavelength in the range 5-20 nm), as well as particle beams, such as ion beams or electron beams.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which:

Figure 1 depicts a lithographic projection apparatus according to an embodiment of the invention;

Figure 2 depicts a distributed Bragg reflector suitable for use in the present invention;

Figure 3 depicts the use of two distributed Bragg reflectors to create an element with adjustable reflectivity;

Figure 4 depicts a portion of a programmable mask according to the present invention;

Figure 5 depicts a portion of a further programmable mask according to the present invention;

Figure 6 depicts a portion of a piezoelectric-actuator-driven programmable mask according to the present invention; and

Figure 7 depicts a portion of an electrostatic-actuator-driven programmable mask according to the present invention.

In the Figures, corresponding reference symbols indicate corresponding parts.

Embodiment 1

Figure 1 schematically depicts a lithographic projection apparatus according to a particular embodiment of the invention. The apparatus comprises:

- a radiation system Ex, IL, for supplying a projection beam PB of radiation (*e.g.* EUV radiation), which in this particular case also comprises a radiation source LA;
- a first object table (mask table) MT provided with a mask holder for holding a mask MA (*e.g.* a reticle), and connected to first positioning means for accurately positioning the mask with respect to item PL;
- a second object table (substrate table) WT provided with a substrate holder for holding a substrate W (*e.g.* a resist-coated silicon wafer), and connected to second positioning means for accurately positioning the substrate with respect to item PL;
- a projection system ("lens") PL (*e.g.* mirror group) for imaging an irradiated portion of the mask MA onto a target portion C (*e.g.* comprising one or more dies) of the substrate W.

The source LA (*e.g.* a laser-produced or discharge plasma source) produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after having traversed conditioning means, such as a beam expander Ex, for example. The illuminator IL may comprise adjusting means AM for setting the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator IN and a condenser CO. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its cross-section.

It should be noted with regard to Figure 1 that the source LA may be within the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors); this latter scenario is often the case when the source LA is an excimer laser. The current invention and Claims encompass both of these scenarios.

The beam PB subsequently intercepts the mask MA, which is held on a mask table MT. Having been selectively reflected by the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning means (and interferometric measuring means IF), the substrate table WT can be moved accurately, *e.g.* so as to position different target portions C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB, *e.g.* after mechanical retrieval of the mask MA from a mask library, or during a scan. In general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in Figure 1. However, in the case of a wafer stepper (as opposed to a step-and-scan apparatus) the mask table MT may just be connected to a short stroke actuator, or may be fixed.

The depicted apparatus can be used in two different modes:

1. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (*i.e.* a single "flash") onto a target portion C. The substrate table WT is then shifted in the x and/or y directions so that a different target portion C can be irradiated by the beam PB;

2. In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", *e.g.* the y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (typically, $M = 1/4$ or $1/5$). In this manner, a

relatively large target portion C can be exposed, without having to compromise on resolution.

The programmable patterning means of the present invention consists of a plurality of reflective elements arranged in a grid. The surface of each reflective element may, for example, be approximately 10 µm x 10 µm and the complete programmable patterning means may, for example, be approximately 25 mm x 25 mm.

Figure 2 shows a distributed Bragg reflector of the kind used in the present invention. The distributed Bragg reflector is comprised of a multilayer stack 10. For a distributed Bragg reflector for EUV the stack 10 may, for example, be comprised of layers 11, 13, 15 of molybdenum, interposed with layers 12, 14, 16 of silicon. The high reflectivity (of approximately 70%) occurs due to the constructive interference of the radiation reflected from the upper surfaces 11a, 13a, 15a of the metal layers 11, 13, 15. In order to maximize the construction of this interference, the distance between the upper surfaces 11a, 13, 15a of the metal layers in the direction in which the radiation is directed (i.e. taking into account the angle of incidence) should be a multiple of half of the wavelength of the radiation used. Although the distributed Bragg reflector in Figure 2 is shown with three metal layers, it will be appreciated that in practice a much larger number of layers, for example 80 layers, may be used for optimum reflectivity. Further information on distributed Bragg reflectors may be found in EP 1,065,532A and EP 1,065,568A which are incorporated herein by reference.

Figure 3 schematically represents a reflective element of a programmable mask used in the present invention. The programmable mask is comprised of a plurality of the reflective elements arranged on a surface onto which the projection beam of radiation is incident. Each of the reflective elements can be individually controlled, such that by changing the reflectivity of some of the reflective elements, the beam reflected by the programmable mask contains a desired pattern in its cross-section. Each of the reflective elements is comprised of two distributed Bragg reflectors 10, 20. When the distance D2 between the upper surfaces 15a, 21a of the metal layers of the two distributed Bragg reflectors 10, 20 in the direction of the beam of radiation (i.e. taking account of the angle of incidence of the beam) is a multiple of half the wavelength of the beam of radiation the reflections from the two distributed Bragg reflectors 10, 20 constructively interfere and the total reflection is at a maximum. When, however, the distributed Bragg reflectors 10, 20

are positioned such that the distance D2 is altered from the previous position by a quarter of the wavelength of the radiation, as shown in Figure 3, then negative interference between the reflection from the first distributed Bragg reflector 10 and the reflection from the second distributed Bragg reflector 20 will result in substantially zero reflectivity of the reflective element. By adjusting the value of the distance D2 to be in between these two positions, intermediate levels of reflectivity, between zero and the maximum, can be attained. Preferably the distance D2 can be adjusted to any one of approximately 200 positions between the positions for the maximum and minimum reflectivity. Alternatively, the position of the distributed Bragg reflectors may be controlled to allow a continuous range of settings of distance D2.

Figure 4 schematically shows three reflective elements A, B, C of a programmable mask according to the present invention. Reflective element A is comprised of two distributed Bragg reflectors 31, 32, as described before, and a piezoelectric-actuator 33. Similarly, reflective element B is comprised of distributed Bragg reflectors 34, 35 and piezoelectric element 36 and reflective element C is comprised of distributed Bragg reflectors 37, 38 and piezoelectric-actuator 39. By applying voltages to the piezoelectric-actuators 33, 36, 39 the position of the lower distributed Bragg reflectors 32, 35, 38 may be moved relative to the upper distributed Bragg reflectors 31, 34, 37, respectively, thereby altering the reflectivity of each of the reflective elements A, B, C.

As shown in Figure 4, each of the reflective elements A, B, C have a discrete piezoelectric element 33, 36, 39, respectively. However, two or more of the reflective elements may have a common piezoelectric element. The piezoelectric effect is limited to a region immediately surrounding the voltage applied to a piezoelectric element. Therefore, by only providing the voltage to a region of the common piezoelectric element corresponding to a particular reflective element, only the lower distributed Bragg reflector of that reflective element will be moved and therefore only the reflectivity of that reflective element will be adjusted. Thus, by attaching a plurality of electrodes to a single piezoelectric element, a plurality of reflective elements sharing the piezoelectric element can be controlled.

Figure 5 depicts a further variant of this embodiment. Each of the reflective elements D, E, F, has its own lower distributed Bragg reflector 42, 45, 48, the position of which may be adjusted with piezoelectric-actuators 43, 46, 49. However in this case the

reflective elements D, E, F share a common upper distributed Bragg reflector 41. Depending on the size of the programmable mask, the upper distributed Bragg reflector 41 may be common to all the reflective elements in the programmable mask or just to a section of it. As before, the reflective elements may share a common piezoelectric element.

Figure 6 shows the embodiment of Figure 4 in more detail. The upper distributed Bragg reflector 51 of each reflective element A, B, C is supported by supports 54, 55. The supports may, as shown in Figure 6, be columns between the reflective elements A, B, C. Alternatively, a mesh-like structure may be formed onto which the upper distributed Bragg reflectors 51 are placed. The lower distributed Bragg reflectors 52 are supported on a piezoelectric layer 53. The gap 58 between the two distributed Bragg reflectors may be filled with a porous material, provided it is substantially transparent to the beam of radiation, or may be vacuum. The piezoelectric element 53 has upper and lower electrodes 56, 57 respectively, to provide the voltage to actuate the piezoelectric actuators and thereby alter the size of the gap 58 between the upper and lower distributed Bragg reflectors. The upper electrode layer 56 may be common for all the reflective elements, the actuation signal being provided by the lower electrode layer 57. Alternatively, the lower distributed Bragg reflector may be used as the top electrode. As discussed before, the upper distributed Bragg reflector and/or the piezoelectric element may be common for some or all of the reflective elements.

Embodiment 2

Figure 7 depicts an alternative embodiment of the present invention in which, by using the top and bottom distributed Bragg reflectors 61, 62 as electrodes, the distance between the distributed Bragg reflectors can be adjusted using electrostatic attraction. In this case the support 64, 65 would need to be used to provide the signals to the distributed Bragg reflectors and the gap 68 between the distributed Bragg reflectors would need to be electrically non-conductive. The gap may be a vacuum or filled with a porous material.

As the electrostatic force between the two distributed Bragg reflectors 61, 62 increases, the supports 64, 65 bend, varying the separation between the distributed Bragg reflectors.

An advantage of this embodiment is that it requires less than the tens of volts needed to produce the required movement of the piezoelectric elements.

Whilst specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the invention.

CLAIMS:

1. A lithographic projection apparatus comprising:

- a radiation system for providing a projection beam of radiation;
- a support structure for supporting programmable patterning means, the programmable patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate;
- a projection system for projecting the patterned beam onto a target portion of the substrate,

characterized in that the programmable patterning means comprises a plurality of reflective elements, each comprising first and second distributed Bragg reflectors and a means for adjusting their separation;

wherein, in a first position, the separation of the first and second distributed Bragg reflectors produces destructive interference between the reflections from the first and second distributed Bragg reflectors and the reflectivity of the reflective element is relatively low; and, in a second position, the separation of the first and second distributed Bragg reflectors produces constructive interference between the reflections from the first and second distributed Bragg reflectors and the reflectivity of the reflective element is relatively high.

2. A lithographic projection apparatus according to claim 1, wherein the actuator for adjusting the position of the first and second distributed Bragg reflectors can be set to a plurality of positions between the first and second positions, providing a range of possible settings of the reflectivity of the reflective element.

3. A lithographic projection apparatus according to claim 1 or 2, wherein two or more of the reflective elements have a common first distributed Bragg reflector.

4. A lithographic projection apparatus according to claim 1, 2 or 3, wherein the projection beam of radiation is EUV radiation and the difference in the separation of the first and second distributed Bragg reflectors between the first and second positions is substantially one quarter of the wavelength of the EUV radiation.

5. A lithographic projection apparatus according to any one of the preceding claims, wherein the means for adjusting the separation of the first and second distributed Bragg reflectors is a piezoelectric-actuator.

6. A lithographic projection apparatus according to claim 5, wherein two or more of the reflective elements have a common piezoelectric element but each reflective element has at least one electrode associated only with that reflective element for producing a piezoelectric effect local to that reflective element.

7. A lithographic projection apparatus according to claims 1 to 4, wherein the means for adjusting the separation of the first and second distributed Bragg reflectors is an electrostatic actuator.

8. A lithographic projection apparatus comprising:

- a radiation system for providing a projection beam of radiation;
- a support structure for supporting programmable patterning means, the programmable patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate;
- a projection system for projecting the patterned beam onto a target portion of the substrate,

characterized in that the programmable patterning means comprises a plurality of reflective elements, each comprising a distributed Bragg reflector and a means for adjusting the position of each distributed Bragg reflector relative to the programmable patterning means such that a phase difference can be created between the reflection from a first reflective element and the reflection from a second reflective element.

9. A lithographic projection apparatus according to claim 8, wherein two or more of the reflective elements have a common distributed Bragg reflector which is distorted locally to produce a difference in the position of the distributed Bragg reflector between said reflective elements.

10. A device manufacturing method comprising the steps of:

- providing a substrate that is at least partially covered by a layer of radiation-sensitive material;
- providing a projection beam of radiation using a radiation system;
- using programmable patterning means to endow the projection beam with a desired pattern in its cross-section;
- projecting the patterned beam of radiation onto a target portion of the layer of radiation-sensitive material,

characterized by said programmable patterning means comprising a plurality of reflective elements, the reflectivity of each of which being determined by the distance between a pair of distributed Bragg reflectors that comprise each reflective element; and by the method further comprising the step of setting the distance between each said pair of distributed Bragg reflectors to provide the desired reflectivity of each reflective element in accordance with said desired pattern.

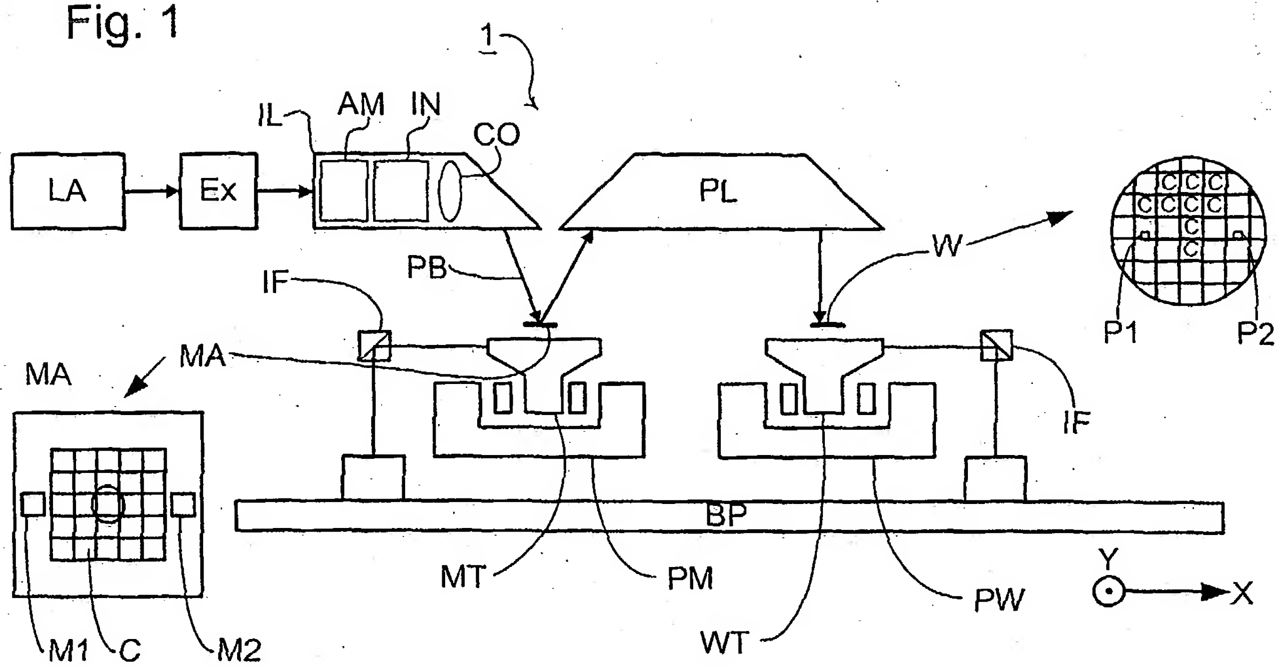
ABSTRACT

Lithographic Apparatus and Device Manufacturing Method

Programmable patterning means for use with a lithographic projection apparatus comprising a plurality of reflective elements A, B, C, each element comprised of two distributed Bragg reflectors 51, 52. The separation D1 between the two distributed Bragg reflectors is adjustable between a first position in which disruptive interference between the reflections from the first and second distributed Bragg reflectors 51, 52 result in substantially zero reflectivity and a second position in which constructive interference between the reflections from the first and second distributed Bragg reflectors 51, 52 result in high reflectivity.

Fig. 6

Fig. 1


1
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LA
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PB
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IF
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P2
IF
BP
MT
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M1
C
M2
C

Fig. 2

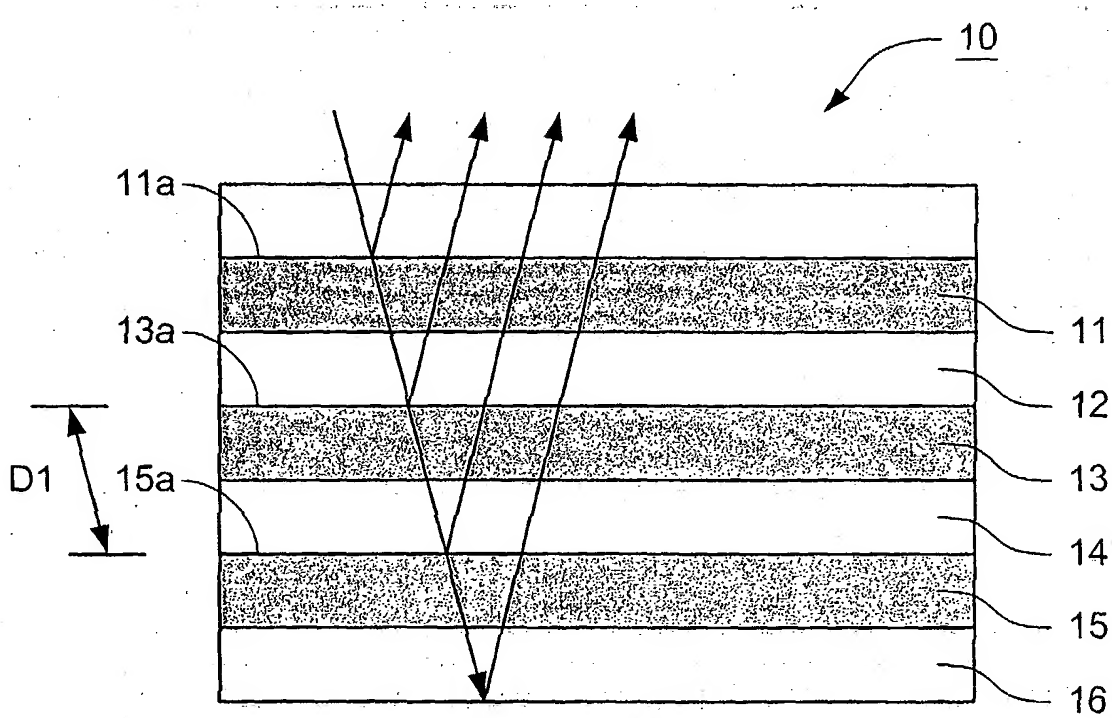
10
11a
11
13a
12
13
D1
15a
14
15
16

Fig. 3

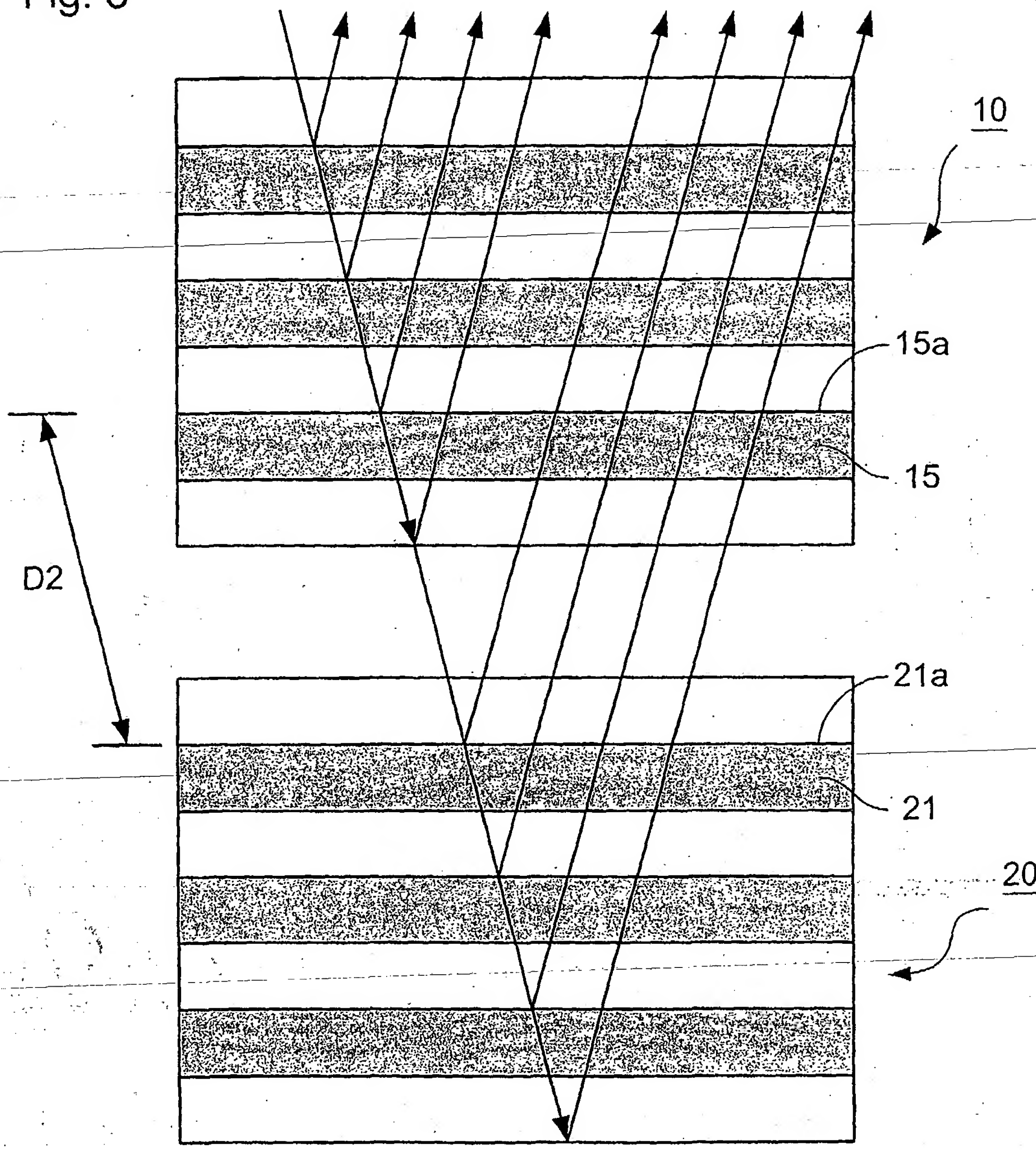

Fig. 4

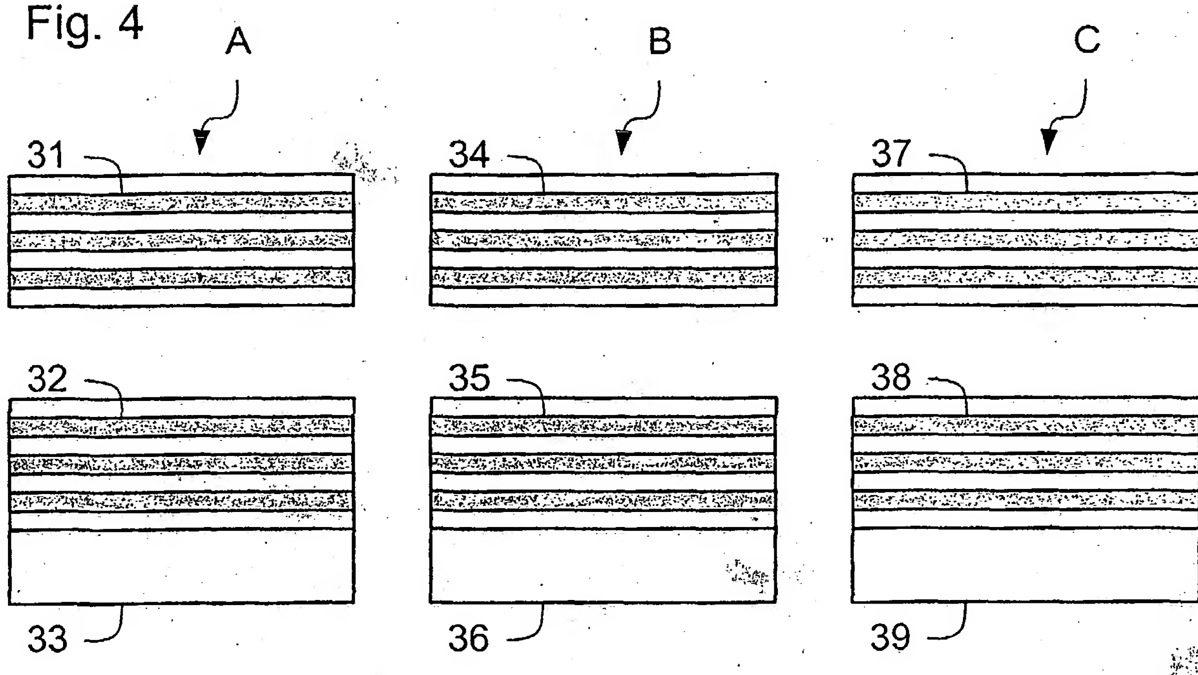

Fig. 5

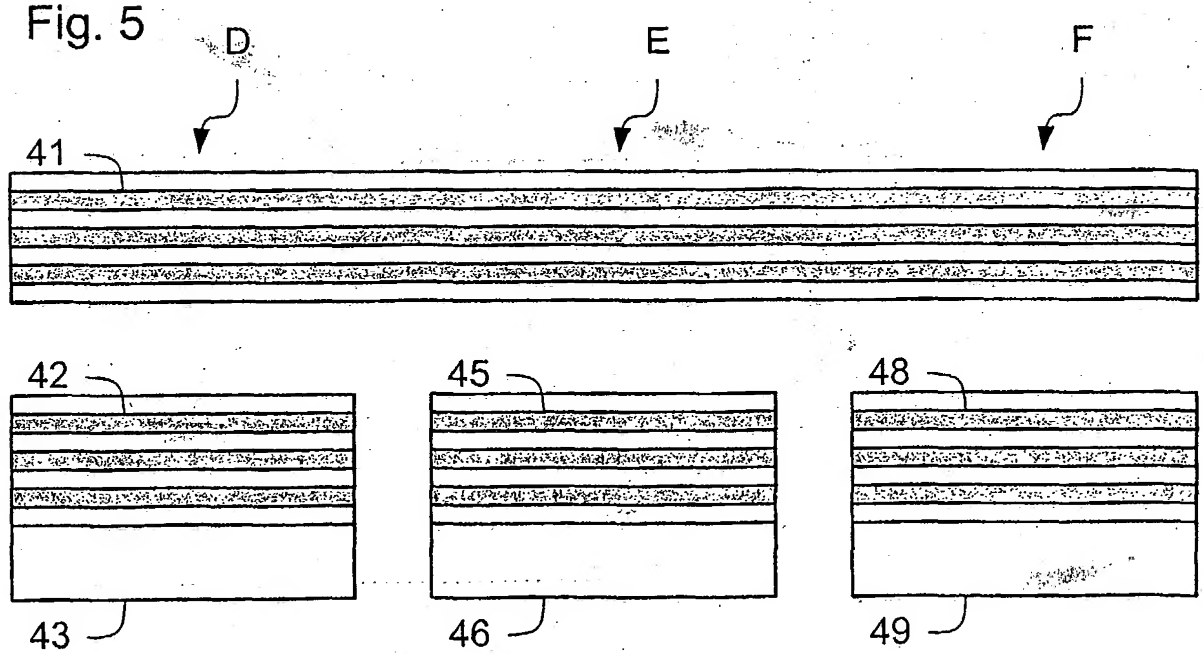

Fig. 6

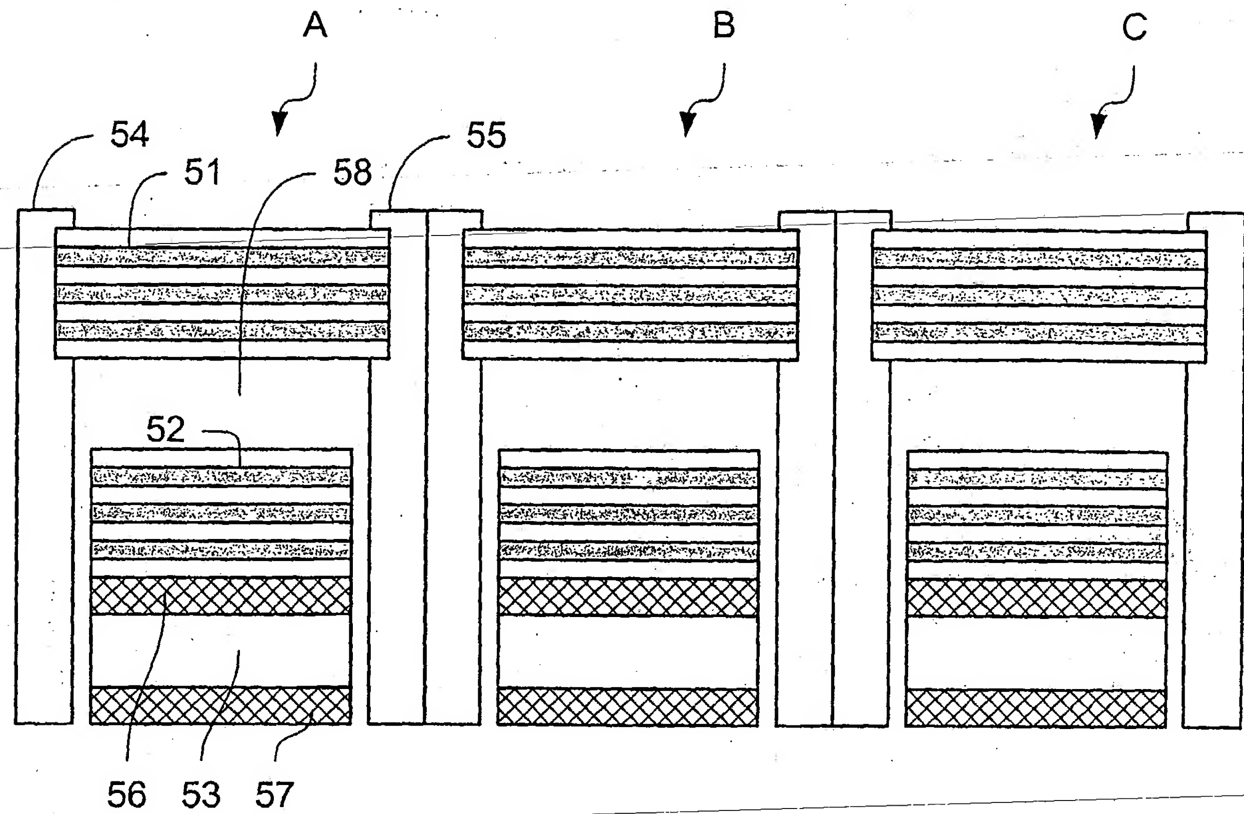

Fig. 7